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Automatisierungs-
technische Praxis

Three ways to automation solutions
matched to users' needs

SPECIAL EDITION

Oldenbourg

Three ways to automation solutions matched to users' needs

Foreword

In the discussion on innovations in process automation, the terms *Fieldbus* and *Remote I/O* and the related achievable costs savings, simplifications and the information obtained are constantly the focus of reporting. The characteristics of these installation concepts and communication concepts are discussed and wide-ranging visions developed. The real solutions implemented are however, weighted by application area and "outlook", always in the context of all the technologies currently available. Only a common approach in mechanical engineering, electrical engineering and modern information technology will permit further innovative steps to be taken.

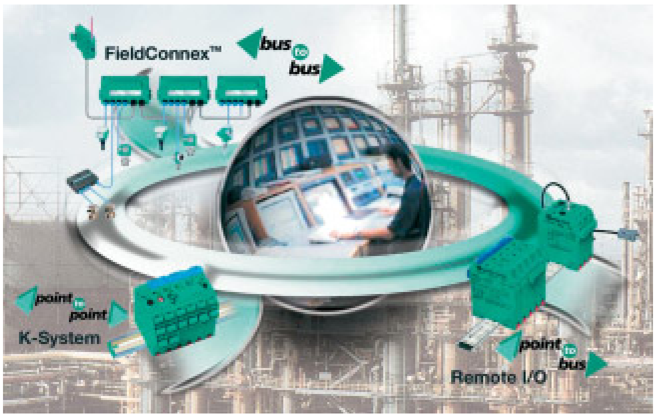
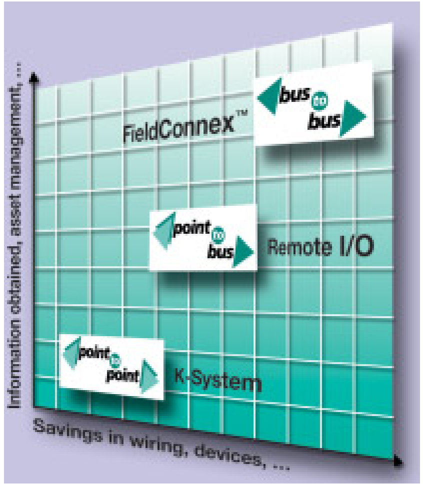


Figure 1: Modern communication concepts for process automation with related product lines (example Pepperl+Fuchs GmbH). The user defines positioning and technology for the signal processing.

During the discussion on the introduction of fieldbus technologies, it is therefore necessary to give greater consideration to three aspects:

Figure 2: Communication concepts for process automation with related product lines from an interface manufacturer. The user defines the technology for the signal processing.



a) The frequently quoted example of factory automation with its rapid acceptance of fieldbus technology cannot be transferred directly to process automation. The reasons for this situation are the very different characteristics of these two application areas, see Table 1.
b) Along with the two "new" communication concepts already mentioned, fieldbus and Remote I/O, the "classic" 4–20 mA signal in conjunction with the point-to-point connection is in practice by far the most frequently applied standard for the tasks in process automation. This situation is predominantly due to very long service life of process plant (15–20 years) compared to that in factory automation, and the intensive standardization efforts undertaken by the German chemical industry. Today 4–20 mA technology has been proven millions of times over in worldwide use.
c) The three communication concepts have a technologically and commercially justifiable right to co-existence. The times of technological preferences are over; cost-effectiveness alone defines the use of the technologies. On this topic see Figure 2, which shows the three concepts as segments of a portfolio with the axes Cost *reduction* and *Information obtained*. However, this is only a snapshot as the boundary conditions for automation projects are very complex and it is only rarely that one project can be directly compared with another. In an illustration with variables such as *"System-compliant expansion of old plants"* or *"Limited requirements on the maintenance personnel"*, for example, the 4–20 mA segment would have a stronger position and the fieldbus segment a weaker position.

Table 1. Reasons for the varying acceptance of fieldbus in factory and process automation.

Factory Automation	**Process Automation**
The service life of the plant is limited and similar to the cycles for information technology	The service life of the plant is 15–20 years and more and thus much longer than the IT cycles
No specific standard signals available	The 4–20 mA standard signal has been and continues to be familiar and used worldwide
The size of the investment and thus the significance of protection of investment per plant is limited	The size of the investment and thus the significance of protection of investment per plant is high
Explosion protection tasks have no high priority	Explosion protection tasks as well as availability and safety of the plant are very important due to the possible consequences and result in conservative behavior on the part of the operating organizations [2]
For signal transmission, speed plays the dominant role	Speed does not play a dominant role on signal transmission
Consequence **Rapid and complete acceptance of fieldbus technology**	**Consequence** **Hesitant and step-by-step acceptance of fieldbus technology**
	Step 1: Retention of 4–20 mA technology, possibly with use of HART technology Step 2: Combination of 4–20 mA technology and fieldbus via RIO technology Step 3: Use of fieldbus technology

For the user, innovations are both necessary and required to remain competitive, but based on the motto *Everything in good time and within the bounds of the feasible,* the user should be given the opportunity to realize innovations for his plant's systems based on his specific situation and expectations (timing, concept and resources). For the user, technology segmentation is a good decision aid.

For an equipment manufacturer, the segmentation is a challenge and a burden at the same time! On the one hand the manufacturer must satisfy, with his developments, the requirement of some users in the fieldbus segment for digitalization and obtaining information so that manufacturer can secure competitive advantage. On the other hand the manufacturer is under pressure not to ignore the already established segments and the customer groups in them. This situation results in an increase in the number of device variants with the concomitant development effort and costs. The balancing act is made more difficult by the fact that fieldbus technology, despite its standardization in IEC 61158, does not comprise a single standard. There are currently no less than 18 fieldbus systems [1] listed as covered by IEC 61158.

As a result the equipment manufacturers have varying product presences in the segments and the one or the other equipment manufacturer will not cover all segments for commercial or technical reasons.

As a market leader and specialist for interface technology, Pepperl+Fuchs has the clear objective of serving and supporting *all three segments* equally with highly innovative product lines, and also creating transitions between the segment technologies (see illustration in Figure 1). In this way the user can, like on a roundabout, “turn off” into one of the segments without hindrance when the user considers the change opportune. This situation helps achieve the best possible payback periods for both new investments and investments already made.

In this three-part article, the three segments and their related concepts, technologies and properties are discussed, the possible methods of transition between the segments explained and examples of current equipment technology given. It is the authors' objective to assist users in making decisions about how, under specific boundary conditions, an existing plant can be modernized or extended, or a new plant can be optimally automated.

In this respect the reader is also referred to FuRIOS Study by Infraserv GmbH [3], which is closely related to this series of articles. Extracts from this study can be requested from the authors of this article.

The K-System – the firewall for analog signals

Classic signal transmission is performed using 4–20 mA analogue signals and “point-to-point connections”. This technology impresses with its signal integrity, its resilience and its worldwide acceptance. (Example Pepperl +Fuchs).

The most frequently used communication method in process automation is still analog transmission with its focus on the 4–20 mA current signal.

The classic plant structure has now been derived from this technology for more than 30 years: sensors and actuators in the field, control system and signal conditioning using interface assemblies in the control room and in between the direct point-to-point connections with their distributors and control cabinets.

Worldwide acceptance and use

Over 30 million field devices, that is approx. 75 % of the volume installed worldwide, today utilize the 4–20 mA current signal (with or without additional HART functionality). This technology represents not only *the current standard* in process automation, but at the same time makes it clear that it will continue to retain this status for considerable time to come. A somewhat unusual finding in the age of aggressively marketed and rapidly adopted fieldbus technology. This strong position can be traced back to the following reasons, among others:

- As early as the 60’s the chemical industry pushed extensively for the introduction and for the national and international acceptance of this standard.
- Due to the high service life expectancy of process plant, this standard is to be found in all plants set up in recent decades. In this period of continuity, unachievable for modern technologies, the 4–20 mA analogue signal has become established and proven as a fixed constant in plant planning.
- With HART technology, the 4–20 mA analog signal has obtained its modern linkup to the world of digital data transmission. This linkup is provided without change to the existing plant concepts and with the retention of the existing cable routes.

Finding the right way

Today, 4–20 mA technology (point to point K-System in Fi-

Table 2. Product lines for point-to-point connections (Pepperl + Fuchs).

“Point-to-point” interface technology		
E-System	**K-System**	**HiD2000 System**
Interface modules as Eurocards in 19” racks	**Interface modules as compact modules on rails**	**Interface modules as plug-in modules on the motherboard**
Suitable for Ex i		
HART communication		
SIL categorization as per IEC 61508		
PACT*ware*™ Graphic User Interface (GUI)		
Design preferred by the chemical industry for many years	Extremely versatile, highly veriable	Optimized for connection to control systems

gure 2) has features that, *given corresponding boundary conditions for the automation task in hand,* render the new or continued use of this technology not only appropriate for the user, but also attractive. *"Fieldbus may be in, but the 4–20 mA signal remains very resilient",* on this basis every user should, as part of his decision analysis, identify the most cost-effective and efficient solution depending on the task, size of the plant, costs, opportunity for maintenance, plant reliability, payback period and similar criteria.

For the new construction of larger plant with flexible processes, in future a complete fieldbus installation will very probably be the first choice. Batch plants with their changing recipes and processes are just one example of many. The technology of the point-to-point connection will, however, also continue to be considered for new plant as soon as the plant have fixed processes and the focus is on long payback periods defined by cost-effectiveness.

In the following we would like, together with the articles on the segment "point to bus Remote I/O – the gateway to the fieldbus" and the segment "bus to bus FieldConnex™ – power for the fieldbus" to support the user during such a decision process.

The 4–20 mA plus points at a glance

- The 4-20 mA interface is in use worldwide and is to be found on nearly all field devices from any manufacturer.
- The 4–20 mA signal is present continuously and the information (= the measured value to be transmitted) thus has high availability.
- Installation and maintenance require neither new tools nor special skills.
- The separately wired measuring circuits with their few components are easily understandable and ease the proof of intrinsic safety.
- Additional information is transmitted with the aid of the HART concept.
- Up to 400 mW can be supplied to the field devices in a hazardous area with intrinsic safety.
- Modern interface modules provide the user a variety of monitoring and evaluation functions that can be used to significantly increase performance. These modules are much more than just connection modules.

Simple technology increases plant safety

Plant safety is always a key issue, not least due to the establishment of the international standards IEC 61508 and IEC 61511 in large parts of the world.

On the aspect of relevance to safety, the transmission and evaluation of signals using conventional interface modules is in some areas superior to bus technology. One reason is the integrity of the signals with point-to-point wiring. The wiring is very reliable and has high availability. Moreover, the use of devices that are as simple as possible and the related simple transmission of the signals are of particularly high relevance to safety considerations. The failure behavior of such devices is stable and known, unlike the behavior of more complex devices. Conventional modules such as analog transmitters, electrical isolators or isolating amplifiers often do not require software and thus avoid the recurring subject of software updates with their relevance to safety and their validation.

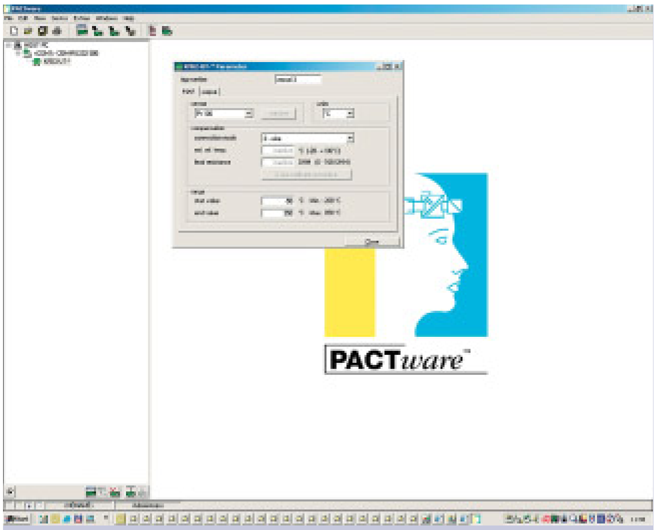


Figure 3: Screenshot from the Graphic User Interface PACT*ware*™.

"Firewall" against interference

The integrity and the availability of all signal levels is an imperative requirement for the efficiency of the plant, and also for the plant safety. No signal is allowed to affect and/or change the measured values from another measuring circuit due to a wire-break or a short-circuit, as important process variables such as product quantities, quality features, costing variables and similar are derived from the measured signals. The 4–20 mA signal meets this requirement provided modern interface modules are used for its transmission, modules that protect against signal loss and at the same time monitor all measuring circuits in the field.

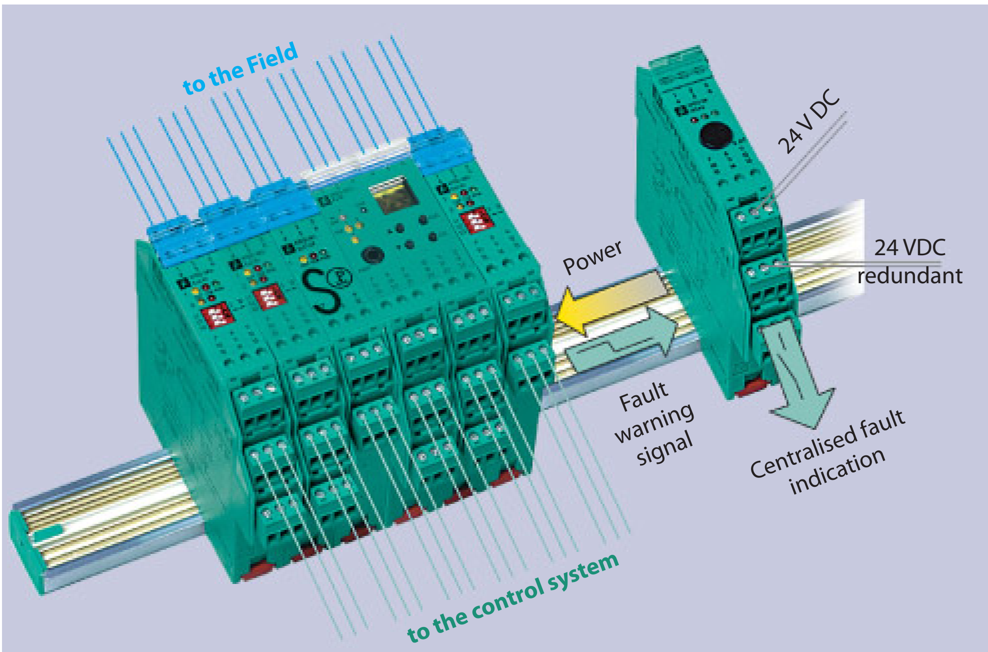


Figure 4: The modular K-System with rail mounting.

Thus, e.g., the electrical isolation of the measured signals is the best means to reliably prevent from impairing the electrical isolation within complex plants and for signal sources of unknown origin. High-quality, non-interacting isolating modules ensure maximum immunity to interference here and thus provide a sort of "firewall" functionality for conventional automation technology, similar to the firewalls familiar from IT.

4–20 mA: intelligent due to HART

HART ("**H**ighway **A**ddressable **R**emote **T**ransducer") is a variant of the digital field communication that already contains much of the functionality of fieldbus technology. The undisputed advantage is that the classic 4–20 mA technology with the infrastructure of the point-to-point connection is used for the signal transport without change. Here a digital signal is modulated onto the analog signal using the FSK (**F**requency **S**hift **K**eying) method. This digital signal transmits information on, e.g. values for limits or diagnostics together with the measured value, without affecting the analog functionality. In addition, using the HART protocol it is also possible to integrate the field devices in engineering tools or master systems. The communication with the HART device is performed over the existing cabling, an invaluable advantage on the modernization of existing plants.

The online communication between process control system/PC and the field devices that support HART is performed using HART multiplexers. Here information such as measuring range, calibration state and status, tag number, manufacturer's ID, etc. cannot only be read from the intelligent field devices, but also changed and saved again in the device. HART multiplexers are located in the measuring room (or in the switch room) and are connected in parallel with the 4–20 mA wiring there. Due to the modern design of the multiplexers, bi-directional links to up to 7936 field devices (maximum configuration) can be established in expansion steps of 16 or 32 using one RS 485 connection.

Interface modules, more than just connections

The interface modules available today feature both wide-ranging coverage of the applications and compliance with the related plant concepts.

An example of the *consideration of different plant concepts* is shown in Table 2. Here the requirements of the "point-to-point" segment are excellently covered with three product lines. The upgrading of old plants is considered, as are the demands for the latest technology. Both Eurocards and compact modules on rails (the K-System) or the motherboard variant (the HiD2000 system) are available. Many components in these three systems, with their mechanical differences, comply with current requirements in relation to IEC 61508 (characteristics for risk reduction, Safety Integrity Level, SIL), in relation to the explosion protection method Ex-i (intrinsic safety) in accordance with ATEX and provide digital communication via HART. Moreover, they can be operated in a uniform manner using the **PACT*ware***™ software application (Figure 3).

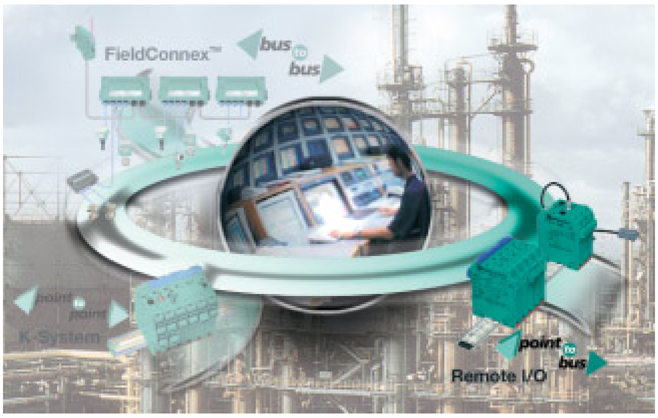
Some examples from the K-System (Figure 4) demonstrate the versatility and practicality of the design of current interface technology:

- Due to the latest microcontroller technology, many devices are multifunctional. This feature reduces the wiring effort and the control cabinet space.
- The uniform and self-explanatory menu layout eases manual adjustment, the graphic display indicates all device settings both on initial commissioning and on making changes to parameters. In addition, the majority of devices have a serial interface for setting parameters using a PC.
- Speed sensors monitor rotational speeds or frequencies and at the same time signal a wire-break or short-circuit on the signal wires. Relays are available to monitor the limits; the relays can be used as either MIN or MAX contacts. A further input is used for startup bridging. Using this input shutdown functions can be cleared and temporarily bypassed.
- Frequency-current converters monitor, along with their task as measurement transducers, also the input frequencies for limits and signal when limits are reached using a relay contact.
- Transmitter power feed devices can, along with their power feed function, also evaluate 0/4…20 mA sensor signals. Active sources, 2 and 3-wire transmitters can be connected to the inputs. Analog current outputs and limit relays are available as outputs.
- Valve control modules supply power to solenoid valves. Here the current consumption of the field circuit is monitored for a wire-break or short-circuit and the status signaled to the control system. At the same time, on the input side the user has various means of access for choosing between "manual" and "automatic".
- Isolated switch amplifiers use the 2:1 method to transmit two binary signals over one pair of wires. This method reduces the field wiring by 50 % and makes subsequent extensions to the system possible despite cables without any spare cores.
- Almost 80 % of the interface modules in the K-System provide modern safety technology in accordance with the international aspects of IEC 61508/IEC 61511 – in the low cost device standard.

Conclusion

"Point-to-point" remains topical not only due to the number of plants instrumented and operated using this technology, but also because it is technologically justified for certain plant tasks. Modern interface modules are to be thanked for this success; these modules not only amplify, convert, isolate or limit the signals, but also undertake monitoring functions and communicate with the higher-level control system.
For setting up large new plants with a free choice of topology and transmission technology, the alternatives of Remote I/O or fieldbus could be the more appropriate solution. These technologies and the possible methods of transition between the individual technologies will be covered in two further articles.

Remote I/O, more than a gateway to the fieldbus



Modern communication concepts for process automation with related product lines, in this case remote I/O. The user defines positioning and technology for the signal processing.

Introduction

Unlike factory automation, innovations in process automation take place at a measured pace and in steps. The reasons for this situation are the long service life and the large investment required for process plants, which prevent short-term changes to the plant on the occurrence of a technological advance. The pronounced safety requirements of the sector also act against rapid change. *Don't reject the proven over hastily and introduce the new cautiously:* this is the principle used in process technology to successfully address the pressure for increased efficiency in recent years. Particularly in the communication between field devices and master system, migration models between conventional and new technology have not only grown but also lastingly proven themselves. “Remote I/O” is the term for the concept that connects the classic 4–20 mA technology with the new fieldbus technology.

However, in the meantime it has become clear that Remote I/O is more than just a preliminary stage on the way to fieldbus technology. Along with, on the one hand, the proven and technically unchanged 4–20 mA technology employed and, on the other hand, the innovative fieldbus technology, Remote I/O is today a third independent segment that can represent the best solution for many applications with certain boundary conditions. Here the size and the expected life of the plant play just as much a role as the physical situation or the “proven in use” that is so important in many cases.

Purpose and expectations

Remote I/O as fieldbus node

In conventional technology with the widespread use of the 4–20 mA signal, the field devices in a plant are individually wired to the control system or the master system based on the principle of the point-to-point connection with isolating cabinets and terminal blocks inserted in between. This configuration requires both wiring effort and space, however for certain tasks it is also certainly advantageous and offers interesting characteristics.

Remote I/O (RIO) are circuits that retain the 4–20 mA devices and their individual connection without any change in the field, but replace the complex individual wiring to the control side with a single bus connection. RIOs are thus bus nodes for a fieldbus system with all the related advantages and possibilities. Technologically, however, there is a major difference to fieldbus: the field signals are not transmitted to the remote I/O system purely digitally, but continue to be transmitted as analog signals. The field signals are then digitized in the remote I/O.

Remote I/O systems can be installed in the safe area in a control cabinet or on-site in the field in a distribution box. For applications in the chemical industry, on-site installation often means areas with zone 1 or 2 potentially explosive atmospheres. The signal circuits in the RIOs are predominantly designed in the protection method intrinsically safe (Ex i) and are therefore completely suitable for hazardous areas. With the characteristic of decentralized installation in the field, RIOs bring the fieldbus to the field level without changing the conventional field devices and their connector technology! Using the RIOs the analog signals are obtained far out in the field, digitized at an early stage and then fed to the process master system over a bus path. This configuration is advantageous both for the plant topology (installation of the distributors near the field devices) and on the costs side for the wiring.

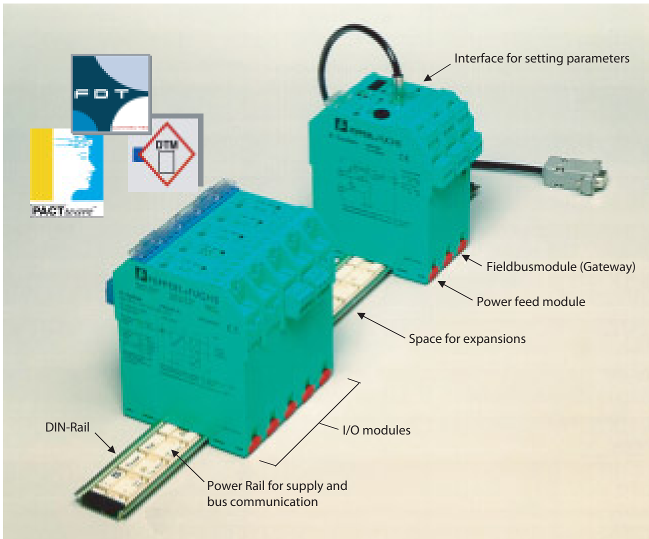


Figure 5: Modular structure of a Remote I/O system based on the example of RPI.

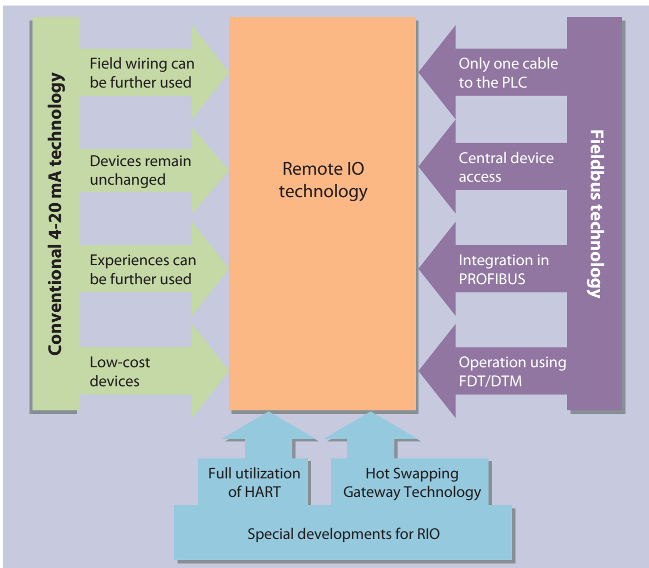


Figure 6: Attractive technology mix for remote I/O.

Module		Function
I/O modules	Isolation switch amplifier	Transmission of digital input signals from the hazardous area to the safe area
	Frequency converter	Transmission of frequencies of digital input signals from VORTEX sensors, magnetic transducers and proximity sensors from the hazardous area including signal processing (frequency meter, flowmeter, rev counter, standstill monitor...)
	Valve control module	Supply and triggering of valves and position controllers in the hazardous area, bi-directional HART communication
	Transmitter power feed device	Power feed to 2 and 3-wire transmitters in the hazardous area, transmission of the analog signals, bi-directional HART communication
	Temperature transducer	Signal transmission from resistance temperature sensors, thermocouples and mV signals
	Transducer	Power feed to transmitters and transmission of analog measured values
	Output isolating transformer	Transmission of current signals to the hazardous area
Gateways	Gateway PROFIBUS DP	Connection of conventional binary or analog sensors to the automation device over PROFIBUS DP
	Gateway PROFIBUS PA	Connection of conventional binary or analog sensors to the automation device over PROFIBUS PA
	Gateway MODBUS	Connection of conventional binary or analog sensors to the automation device over MODBUS
	Gateway MODBUS/Ethernet	Connection of conventional binary or analog sensors to the automation device over MODBUS using Ethernet transmission technology
	Gateway ControlNet	Connection of conventional binary or analog sensors to the automation device over ControlNet
System accessories		Module racks, power rail bus, redundant power feed modules, power supplies, bus couplers, segment couplers, etc.

Figure 7: Typical module range for an RIO system (example Pepperl+Fuchs).

The expectations of the user

With increasingly widespread use of the RIO concept, specific user expectations have arisen that change to suit ongoing technical development. This situation speaks for the high level of acceptance of the RIO technology among users.
What the user expects from a Remote I/O system:

- Modular structure as flexible as possible for adaptation to the characteristics of the plant and type of fieldbus
- Wide range of solutions for signal conversion, fieldbus interface (gateway), redundancy, transmission characteristics, auxiliary power supply, etc.
- Interaction-free replacement/addition of components during operation
- Electrical isolation between the field circuits as well as between fieldbus and auxiliary power
- Use also in potentially explosive atmospheres and processing of intrinsically safe signals as well as signals with increased safety
- Availability of communication with the devices for setting parameters and configuration in parallel with the signal transfer, if possible from a central point
- Monitoring facility for wire-break, short-circuit and field device failure
- Full utilization of HART communication

Numerous manufacturers have taken up this wish list and offer corresponding products. Pepperl+Fuchs as a specialist for interface technology completely addresses the requirements of the market with its Remote I/O systems RPI and IS-RPI.

Modular structure

Remote I/O systems are as a rule of highly modular structure and, depending on the I/O module used, provide connections for up to 8 analog field devices and actuators and up to 16 binary senors. Several modules form an "RIO Station", which in the majority of cases has a fieldbus module (gateway) with a dedicated fieldbus connection and thus represents a fieldbus node. Several stations can be combined to form an "RIO System" with further distribution across the plant.
The range of modules available (differentiation by functions) is very large and also meets special user requirements, see Figure 7.

RIO with attractive technology mix

Attractive key position

RIO technology profits significantly from its central position between conventional technology and fieldbus, see Figure 6. It adopts characteristics from both 4–20 mA technology and from fieldbus technology and is becoming even more powerful due to manufacturer developments especially for RIO.

Gain due to conventional 4–20 mA technology RIO benefits from

- The unchanged field installation comprising devices and their point-to-point connections to the Remote I/O,
- The continued use of low-cost 4-20 mA devices
- The continued use of the existing know-how, e.g. during commissioning, maintenance and service.

Gain due to fieldbus technology RIO provides

- Low-cost and space-saving wiring from the Remote I/O to the control room
- The possibility of central access to all devices, e.g. from a maintenance system
- Depending on the interface manufacturer, operation using the advanced FDT/DTM concept

Gain due to special developments available for RIO are

- Extensive diagnostics features due to access to the full HART functionality of the field devices using the integrated HART multiplexer technology
- Dedicated, channel-specific diagnostics information from the RIO modules (limits, short-circuit, wire-break, …)
- The possibility of the non-interacting replacement of components during operation ("hot swapping")
- Flexibility for adaptation to different fieldbus systems using "gateway technology"
- The facility for full integration in PROFIBUS using the "RIO for PA" and "HART on PROFIBUS" profiles.

The central position also contributes to the simple and "seamless" design of the transition from conventional technology to fieldbus technology on upgrades, extensions or modernizations of plants:
At stage 1 the 4–20 mA field devices in a conventional system are interfaced to an existing or newly installed fieldbus

system using RIO systems mounted near the application in compact switch boxes (Figure 8). In this way it is already possible to realize a large portion of the potential for reducing costs from simpler wiring and less switching. In addition, with the aid of the HART technology it is also possible to collect diagnostics information on the field devices from a central point and to set parameters.

At stage 2, if necessary, the 4–20 mA devices are replaced by fieldbus devices and the devices connected to the bus. Field devices that are only available in 4–20 mA versions for reasons related to the manufacturer, can continue to be operated on the fieldbus without limitations using the existing RIO systems.

HART, only fully exploited by RIO

HART (Highway Addressable Remote Transducer) is a variant of the digital field communication that has been familiar for some time and that has become the industry standard. It already includes much of the functionality of fieldbus technology, it differs however, in that the analog measured signal is used for the transport of the digital information. For this purpose the measured signal is modulated with a further signal. The two different frequencies of this signal, 1.2 kHz and 2.2 kHz represent the bit contents 1 and 0. In this way additional information can be transmitted without affecting the analog signal and using the existing wiring. This information can originate from the field device and be destined for the process management system or maintenance (limits, diagnostics data, information on manufacturer, device identification, measuring ranges, tag number, among others), however it is also possible to write information – acyclically – to the field device, for instance for setting parameters or configuration.

The HART protocol is a standard feature in the current generation of 4–20 mA devices and is therefore potentially available in all newer plants. The HART information can be utilized with either the classic access via hand-held terminals on-site at the devices or via HART multiplexers.

HART multiplexers are used to tap the digital HART information. HART multiplexers are connected to the 4-20 mA wiring and thus form an underlying, independent service layer that can be used to collect digital information including the process value (this value is also available in digital form) transmit the information digitally to the process master system or an operating tool. The analog signal transmission and the processing of the measured value by the PLC are not affected in any way!

The HART multiplex systems HIS, MUX 2700 and KFD2-HMM16 manufactured by Pepperl+Fuchs make it possible to digitally access configuration and diagnostics data from up to 7,936 HART field devices with the aid of software packages such as **PACT*ware***™. The multiplexers are connected to the automation device via an RS485 interface.

The functionality of the HART multiplexers is integrated in the Pepperl+Fuchs remote I/O systems RPI and IS-RPI and makes it possible to utilize the complete range of functions of the HART technology.

By means of the digital and parallel transmission of the HART information for several devices, faster processing of the HART information is achieved. Process values can now also be cyclically transmitted "purely digitally" more quickly using HART, and therefore also used for control tasks.

Integration in fieldbus systems (PROFIBUS)

Remote I/O are nodes in a fieldbus system and devices on a fieldbus system are typically characterized by uniform behavior independent of manufacturer (device model, operating concept). It is thus understandable that with increasingly widespread use, the market is also requiring such standardization also for RIO devices. PROFIBUS

Figure 8: IS-RPI in the switch cabinet.

has addressed this desire and developed an Application Profile "RIO for PA" (PROCESS AUTOMATION) that, following the realization of this profile in the devices, will result in the devices behaving the same for important functions and therefore make the devices interchangeable to a certain degree.

The profile takes into account both the detailed modular structure of the RIOs and also the pressure for innovation that requires room for maneuver for the manufacturers in the related designs. A basic profile has been specified that concentrates on definitions for interchangeability in relation to standard terms for parameters with the same semantics.

The device model is based on an RIO structure comprising header station and modules with varying functionality that realize the actual channels for the connection of the field devices. Here a channel is considered a logical component, which provides an input value for the cyclic communication over the PROFIBUS MS0 channel and accepts an output value from there. A key aspect of the profile is the definition of uniform data formats for the input and output values for the channels.

For the integration of the different RIO devices in the field bus system, standard functions, e.g., for identification or maintenance, have a high priority. The definitions made for this purpose have been matched with other PROFIBUS profiles and contain both information to be defined both by the manufacturer during device development and by the user during device operation (data sets).

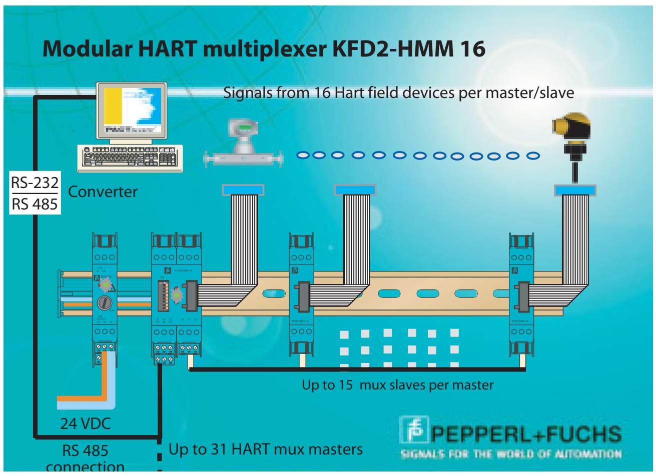


Figure 9: HART multiplexer.

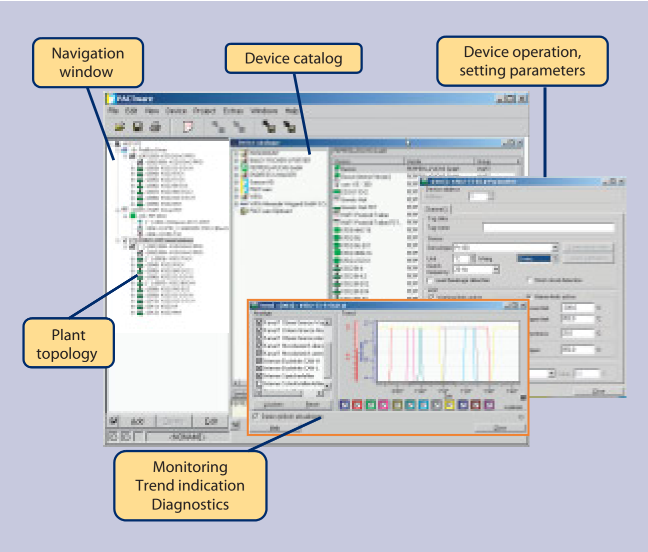


Figure 10: PACT*ware*™ screenshot.

Figure 12: RIO system at the application.

Uniform device management with FDT/DTM

The access to the digital information can only be used as effectively as possible if suitable tools are available. For this purpose the new FDT/DTM concept for device management developed for fieldbus technology and considered to have a very promising future has also been adopted in RIO technology:

- A DTM (Device Type Manager) is a specific description (similar to a data sheet) of a device in software from the device manufacturer. This software also contains the so-called FDT interface.
- FDT (Field Device Tool) is a new standard that is used as an interface between the device-specific DTMs and correspondingly equipped operating tools or engineering tools with FDT support. In this way, various tools can be used for the digital access to the configuration and diagnostics data on the HART devices, such as **PACT*ware***™, as is the case with fieldbus technology.

Process interface with "HART on PROFIBUS"

In view of the large number of HART devices installed, their implementation in existing or new fieldbus systems is an urgent task for the majority of users. The application profile "HART on PROFIBUS" has been specified as an open solution for this purpose on PROFIBUS. The profile is additionally implemented in the PROFIBUS master and slave (above layer 7) to represent the HART "Client-Master-Server" model on PROFIBUS. The HART client application is integrated in the PROFIBUS master and the HART master device integrated in a PROFIBUS slave. This slave, as a multiplexer, takes over the communication with the HART devices. The HART messages are transmitted using an inde-

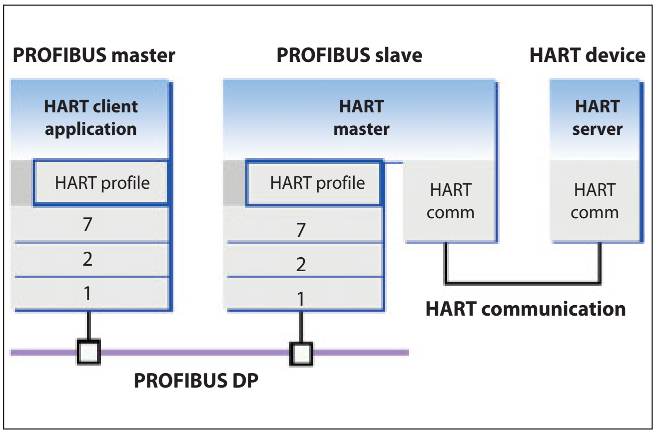


Figure 11: HART on PROFIBUS communication.

Figure 13: RIO system in central arrangement.

		Product features																	
		Modular structure	Compact design (rail)	Suitable up to zone 1	Suitable up to zone 2	Signal circuits zones 0-1	Signal circuits zones 0-2	Hot Swapping	Power supply in Ex housing	Fieldbus connection via gateway	Gateway to PROFIBUS DP	Gateway to PROFIBUS PA	Compatibility with PROFIBUS	HART multiplexer in the gateway	HART multiplexer in the I/O-module	Separate HART multiplex solution	FDT/DTM technology	Full redundancy	Indication of short-circuit and wirebreak
Product line	**Product characteristic**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RPI	Remote Process Interface RPI	■	■		■		■			■	■		■	■		■	■	■	■
IS-RPI	Intrinsically safe RPI	■	■	■	■	■		■	■	■	■	■	■		■		■		■
KFD2-HMM 16	HART multiplex system		■													■	■		
HIS MUX 2700	HART multiplex system															■	■		
PACT*ware*™	Tool for device management																■		

Figure 14: HART multiplexers and RIO product range (example Pepperl+Fuchs).

pendent communication channel, however, PROFIBUS mechanisms (protocol, services) remain unchanged (Figure 11).

Flexibility in the installation and topology

Every plant is different, both in relation to its physical size or the number and position of the field devices as well as in the possibilities for the installation of switch boxes or cable ducts. The prerequisite for the cost-optimized installation of RIO systems is therefore flexibility in the number and arrangement of the RIO components in relation to the field devices installed.

Here there are basically two alternatives (with any number of intermediate solutions):

- Connecting a few field devices very near to the application to a small RIO station (Figure 12) with very short point-to-point connections and longer fieldbus cable
- Coupling a larger number of field devices over longer point-to-point connections using a more centrally positioned, larger RIO station (Figure 13).

The common RIO systems provide complete freedom to adopt any of these variants.

Product coverage meets user's expectations

Many of the users' requirements mentioned at the start, e.g. modular structure, suitability for hazardous areas, hot swapping, compatibility with different fieldbus types and access to HART are met by the RIO products available today. In the context of cost-effective utilization, with RPI and IS-RPI Pepperl+Fuchs offers two systems that differ in structure and some functions. Figure 14 shows a matched product range with identification of the characteristics supported by each.

PACT*ware*™ is a software application for the uniform setting of parameters and/or configuration of field devices, remote I/O systems and communication assemblies in fieldbus systems independent of manufacturer. **PACT*ware***™ has a communication interface as per the FDT standard and is therefore also termed an FDT frame application. With **PACT*ware***™ it is possible to access all HART field devices and RIO modules, provided their technical descriptions are available in the form of a DTM. **PACT*ware***™ also includes a so-called generic HART DTM that can be used for setting the parameters of field devices with HART support for which a specific DTM is not available from the manufacturer. The generic DTM supports the universal commands and standard commands as per the HART specification, which are also used by the majority of HART devices on the market. **PACT*ware***™ provides versatile functions, also including status monitoring and messages, interactive functions and graphic objects such as trend curves, echo curves, graphs over time or device-specific online help integrated in the related DTM (see Figure 10).

Conclusion

The remote I/O technology, originally conceived and developed as a transition and “gateway” from 4–20 mA technology to the fieldbus, has achieved more than this objective. It exactly meets the needs of a market focused on the retention of value and safety, a market that only wants to adopt new technologies cautiously and with low risk. Today this technology represents more than a transition technology. It is the middle segment of three technology segments.

Power for the fieldbus

Modern communication concepts for process automation with related product lines, in this case FieldConnex^{TM}. The user defines positioning and technology for the signal processing.

Introduction

In the discussions on the characteristics and benefits of fieldbus technology for process automation, it has become clear, perhaps surprisingly, that despite all the positive experience with this new technology, the existing alternatives of "4–20 mA" and "Remote IO" continue to be of interest and continue to be used. This fact does not contradict the justified expectation that with the passage of time, fieldbus is the technology of choice for the majority of plants. This situation, however, takes into account the fact that conventional 4–20 mA technology currently represents a realistic alternative for many applications and will also do so in the future due to the very large installed base, the long service life of process plants and also due to complementary developments such as HART and RIO.

As a consequence, plant automation and the communication technology used for this purpose has been segmented into "point-to-point" (4-20 mA with HART), "point-to-bus" (RIO with HART) and "bus-to-bus" (fieldbus), see Figure 2. This situation offers the user the opportunity to select suitable technology for his specific task, his environment and his cost situation. During this selection process the user also has the opportunity to realize a transition from one technology to another without a system discontinuity. On the other hand, this segmentation forces the manufacturers of interface technology to develop and support more product lines.

This article deals with the connection technology between the field devices and the host (master system or control system) as is necessary for fieldbus solutions. Figure 15 shows that this connection technology can be divided functionally into the stages power supply/segment coupling, field distribution/bus termination and integration of conventional signals. The sections that follow are based in this division.

The article is based on the FieldConnexTM system (manufactured by Pepperl+Fuchs) as an example; this system provides various components for the fieldbus systems PROFIBUS PA and FOUNDATION Fieldbus H1 for the design of optimal topologies. A detailed overview is given in Figure 20.

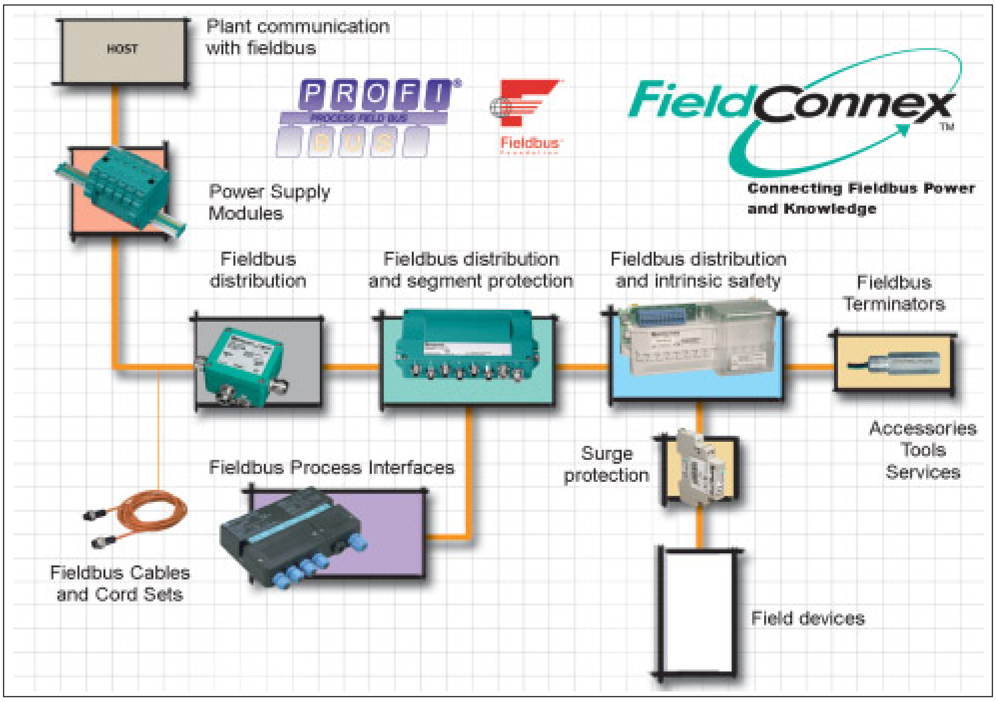


Figure 15: Topology concepts for fieldbus communication based on the example of FieldConnex^{TM}.

Segment coupling and power supply

In process plants the proximity of areas with potentially explosive atmospheres, mostly designed in the explosion protection method intrinsically safe (in the field), and safe areas (e.g. the control room) is a reality. Fieldbus installations must take this situation into account, an aspect that has resulted in the division of the fieldbus topology into intrinsically safe and not intrinsically safe segments.

Segment Coupler

On the PROFIBUS, the segment coupler forms the interface between a PROFIBUS DP network and the PROFIBUS PA segments. With FieldConnex^{TM} this device is implemented in the modular Segment Coupler SK2. The Segment Coupler SK2 converts the digital messages without affecting the fieldbus communication, adjusts the Baud rate, provides the power supply for the PROFIBUS PA segment and enables up to 20 PROFIBUS PA segments to be connected to a PROFIBUS DP spur.

- The Segment Coupler connects the field device MBP transmission technology (Manchester Coded, Bus Powered as per IEC 61158-2, transmission rate 31.25 kBit/s) used on PROFIBUS PA with the PROFIBUS DP physical RS 485 with a transmission rate of up to 12 Mbits/s using the SK2 Gateway module. The Segment Coupler is "transpa-

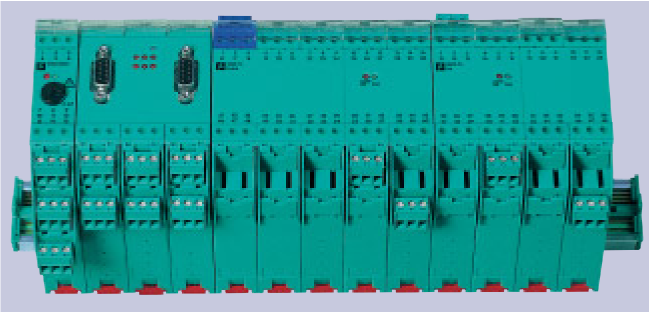


Figure 16: Segment Coupler SK2

Figure 17: FieldBarrier in harsh environment in an oil and gas plant in Hungary.

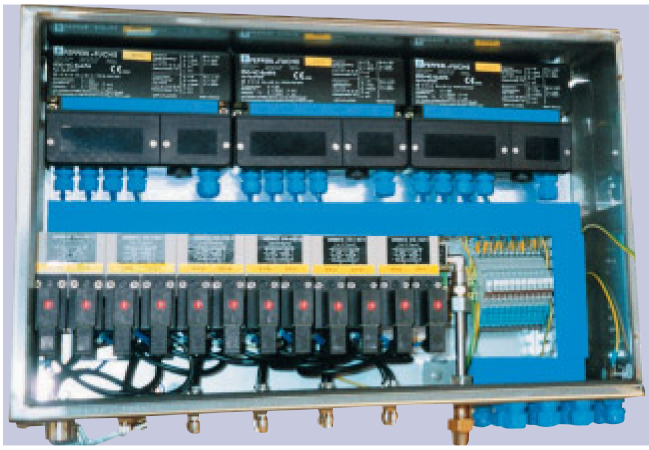


Figure 18: Pneumatic Interface.

rent" in relation to data conversion and it is therefore not necessary to configure it in the master system. The master directly addresses each slave via the Segment Coupler and the total volume of I/O data of 244 bytes for each slave is available without restrictions.

- The Segment Coupler provides the power feed for the field devices using the SK2 Power Link modules. The Power Link modules are available both in the protection method "intrinsically safe" and also without explosion protection. On installation in the safe area and on the usage of FieldBarriers in the explosion protection method encapsulated Ex me, very powerful plant topologies are produced; see the section on FieldBarriers.

Figure 16 shows, as an example, the Segment Coupler SK2 using which a gateway can be combined with up to 20 Power Link modules. Here one module is responsible for one PROFIBUS PA segment and provides max. 400 mA power feed to the segment. In this case all modules are centrally fed via the Power Rail.

Fieldbus Power Supply, Power Conditioner and Power Hub

The Fieldbus Power Supplies, Fieldbus Power Conditioners and Power Hubs supply field devices with power via the FOUNDATION Fieldbus H1 network. They couple the power onto the two-wire fieldbus cable without disturbing the communication signals.

Power Conditioners provide a power supply current of up to 1 A over the fieldbus cable to the field devices connected and enable two redundant power sources to be connected.

Power Hubs provide, in addition, a very flexible power supply concept with fully redundant segment power feed and electrical isolation. Power Conditioners and Power Hubs support alarms and indication of the failure of the power source, low voltage, short-circuit and overload. CREST (Crosstalk Resonance Suppression Technology) prevents resonances and crosstalk between the fieldbus power supply and the internal power supply.

Power Repeater

Power Repeaters supply field devices via the signal cable on a PROFIBUS PA or a FOUNDATION Fieldbus H1 network and improve the digital communication signal within the system, particularly in physically large installations. Independent of the load and the input voltage, the Power Repeater provides a constant voltage for supplying the field devices connected to the bus segment. On the field side the repeater has a fixed integrated bus terminating resistor, on the host side the bus terminating resistor can be enabled as required.

An important application for Power Repeaters is the expansion of a fieldbus network.

Field distribution and bus termination

The fieldbus trunk is not in practice, as is often shown for simplification, fed directly through the field devices, but distributed to the field devices using "fieldbus distributors" using the T-distribution principle. In this way the plant availability is optimized and the isolation of individual devices from the fieldbus simplified. The fieldbus topology produced in this way must satisfy the numerous requirements on the plant, with clear and safe structures for all ambient conditions as well as simple expansion of existing segments or the integration of conventional signals. FieldConnexTM provides a wide range of field distributors for the numerous tasks. The field distributors permit flexible planning of the topology to exactly suit the requirements of the related plant.

Junction Box

The Junction Box enables a fieldbus trunk to be distribu-

Figure 19: „Mini-RIO" for installation in zone 1.

FieldConnex™- system component	Function / Use	Supply of power to the field devices over the bus	Protocol conversion from PA to DP	Network expansion	Conditioning of the power source	Signal boosting	Connection of field devices	Short-circuit and overload protection	Conversion of the power supply from Ex e to Ex i	Short-circuit current limiting for each output	Connection of binary sensors	Control of solenoid valves	Control of pneumatic valves	Integration of analogue and temperature signals	Integration of conventional signals	Avoidance of signal reflection	Protection against overvoltage and current surges	Software tool for topology planning
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Segment Coupler	PA	x	x															
Fieldbus Power Supply	FF	x																
Power Conditioner	FF	x			x													
Power Hub	FF	x			x													
Power Repeater	PA/FF	x		x		x												
Junction Box	PA/FF						x											
Segment Protector	PA/FF						x	x										
FieldBarrier	PA/FF						x		x	x								
Temperature Multi Input	FF													x				
Sensor Interface	PA										x							
Valve Coupler	PA											x						
Valve Coupler	FF											x						
Fieldbus Pneumatic Interface	PA											x	x	x	x			
Fieldbus Pneumatic Interface	FF											x	x	x	x			
Mini-RIO	PA														x			
Fieldbus Terminating Resistor	PA/FF															x		
Surge Protectors	PA/FF																x	
Segment Checker	PA/FF																	x
Cable, Harness, Accessories	PA/FF																	

PA PROFIBUS PA
FF Foundation™ Fieldbus

Figure 20: Interface components with application and functionality based on the example of FieldConnex™.

ted to up to eight spurs for the connection of field devices to the fieldbus segment. This device has a trunk input as well as a trunk output and thus permits the trunk to be looped through. Various cable glands and connector variants are available for this purpose and for the outputs of the spur channels. A fieldbus terminating resistor is integrated and can be enabled as required. A high level of flexibility is also ensured by the different screening and explosion protection methods available, and the varying numbers of outputs.

Segment Protector

Segment Protectors are field distributors with an additional protection function. They convert a fieldbus trunk into several spurs for the connection of field devices to the fieldbus segment. In addition to the characteristics of the junction box, each spur is individually monitored for short-circuit and overload such that a fault on a spur does not have any negative effect on the communication in the rest of the fieldbus segment. Each output is designed for the connection of a field device. The trunk can be looped through; an integrated bus terminating resistor can be enabled as required.

FieldBarriers

In general the issue is to pick up the signals in the plant as close as possible to the sensors and actuators (Figure 17). As these are in general installed in the Ex zones 0 or 1 and intrinsically safe operation is required, it is appropriate to only realize the power supply in explosion protection method "intrinsically safe" in the field distributor box (instead of from the Power Link on). For this task the FieldBarrier technology was developed. The *input* to a FieldBarrier is fed with a relatively high power in explosion protection method Ex e (increased safety). Currently values of up to 400 mA are possible with PROFIBUS, with the FOUNDATION Fieldbus up to 1 A. The individual *outputs* on the FieldBarrier are in explosion protection method Ex i with 40 mA output current each. For reasons of clear structuring and reliability, only one field device should be connected per output. In this way it is ensured that a failure in a field device will only affect this device and will not have any effects on neighboring device, or in the worst case bring the complete fieldbus to a halt. The 40 mA are sufficient to feed high power loads such as valve circuits.
Further characteristics of FieldBarriers:

- The individual outputs on the FieldBarriers are designed so that they are not *mutually interactive* such that the failure of a device, even in the case of a short-circuit, cannot affect the other devices or even cause the complete collapse of the entire segment.
- The FieldBarriers *electrically* isolate the outputs in relation to the bus trunk. As a consequence it is not necessary run the legally stipulated „durable and safe equipotential bonding" out of the hazardous area through the plant. This signifies a considerable cost saving particularly for the

FISCO

is a concept to plan, install, modify and extend intrinsically safe fieldbus installations in zone 1

- Without comprehensive calculations
- Considering only the supply data of the supply device and the field devices
- Using the maximum number of devices and cable length according to IEC
- Without special approval procedures

in a straightforward manner.

FNICO

Is a concept which uses FISCO procedures and rules on fieldbus installations in zone 2 long-term operating costs, as such equipotential bonding is subject to ageing due to the contact resistance and therefore requires regular inspection. *FieldConnex*TM makes it possible to use a hard earth at one end of the fieldbus cable and a capacitive earth at the other end. In this way the effort for running the equipotential bonding from the safe zone into the zones with potentially explosive atmospheres can be reduced.

- The technology used in the FieldBarriers makes it possible to operate each intrinsically safe output for the connection of the bus users with up to 120 m of cable without a fieldbus terminating resistor.
- Due to the high power provided by the Power Link, when the Ex e trunk is continued several FieldBarriers can be connected in series. The number of FieldBarriers is limited on the one hand by the amount of current available and on the other hand by the maximum of 32 bus users that can be connected to a bus segment.

Connecting conventional signals

Even in new plants there will always be conventional signals that must be integrated in the fieldbus communication. The Fieldbus Process Interfaces are used for this purpose. These are devices for connecting a wide variety of sensors or mechanical contacts without fieldbus support [7].

Sensor Interface and Valve Coupler

The *Sensor Interface* enables up to 12 binary sensors or mechanical contacts to be connected to a single fieldbus address.

The *Valve Coupler* is designed for the connection of four low power solenoid valves also to one fieldbus address. This device converts the fieldbus signal into a binary signal for valve control and integrates the eight feedback signals from the end position sensors on the valve into the fieldbus message.

Temperature Multi Input

The *Temperature Multi-Input* enables up to eight resistance temperature sensors, thermocouples, resistance signals and millivolt signals to be connected to the FOUNDATION Fieldbus. The module makes possible the effective configuration of the relevant parameters for the temperature measurement. Sensor diagnostics are supported.

Pneumatic Interface and MiniRIO

The *Pneumatic Interface* combines valve couplers and pilot valves in one functional unit in one housing with pre-assembled connections for fieldbus and compressed air supply, see Figure 18. For more comprehensive installations, it is also possible to integrate FieldBarriers in the housing, which makes possible the control a large number of pneumatic valves using a single fieldbus cable.

The *MiniRIO* combines a large number of conventional signals, such as binary and analog inputs and outputs as well as temperature and frequency inputs with one fieldbus address. Here all features of RIO technology can be utilized, an aspect that offers significant possibilities in conjunction with HART communication. With HART technology, measuring points can be straightforwardly and cheaply connected to the fieldbus using the RIO. Power supply and pre-assembled connection points are combined in one housing here, which can be installed in the field in zone 1, see Figure 19.

FNICO, FISCO and Entity

During the design of the fieldbus topology, the ambient conditions play a crucial role. These conditions range from safe areas through zone 2/class I, div. 2 to zone 1/class I, div. 1. The components for signal transmission must satisfy the requirements of the related safety zones in the same way as the field devices

*FieldConnex*TM provides various versions for this purpose:

- Versions for applications outside hazardous areas
- Versions in accordance with FNICO (Fieldbus Non-Incendive Concept) for installation in zone 2/class I, div. 2; explosion protection method “n”
- Versions in accordance with FISCO (Fieldbus Intrinsic Safety Concept, [3]) for installations in zone 1/class I, div. 1; explosion protection method “i”
- Versions in accordance with Entity for installation in zone 1/class I, div. 1

Product portfolio meets users' expectations

At an early stage fieldbus users employed their practical experience to indicate the need for additional connection technology [4, 5]. The manufacturers have reacted and as a consequence suitable components are available from various manufacturers. An example of a particularly comprehensive product range is the *FieldConnex*TM system [6] that makes it possible for the user to cost-effectively and homogeneously instrument from a single source.

Figure 20 shows the components included in *FieldConnex*TM with their functions.

Conclusion

As easy as it is to connect field devices to a fieldbus system host in principle, the connection technology used for this purpose must be versatile and powerful. Efficient supply of power, field distribution to match the topology, and effective safety mechanisms are necessary among other aspects to fully utilize the performance of fieldbus systems on the automation of process plant. Various manufacturers offer appropriate devices and complete, matched product lines and are thus helping fieldbus to obtain wider acceptance.

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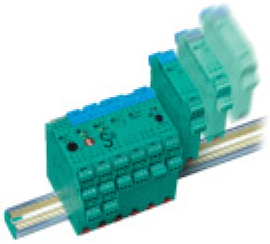
Comprehensive Interface Technology – including sensors for level measurement

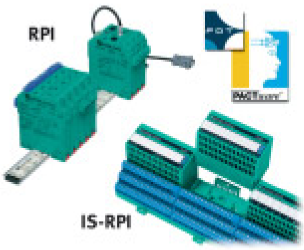
☐ point to point

Point-to-point – single standard signal lines transmit field signals conventionally to the control system.
Two systems are available for conventional instrumentation. The K-System for mounting on DIN rail and the motherboard solution with plug-in modules on the system circuit board.



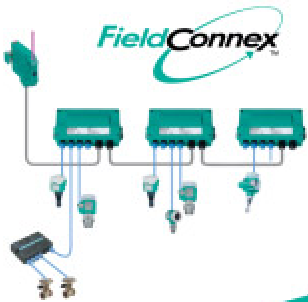
☐ point to bus

Point-to-bus – conventional point-to-point connections for the process and bus connections for the control system.
For applications in explosion protection zone 2 the remote I/O RPI System is used, whilst for direct installation in zone 1 IS-RPI is the first choice – including of HART transfer. Configuration can be carried out using the FDT-compatible **PACT*ware***™ software with the appropriate DTMs.



☐ bus to bus

Installing – connecting – isolating fieldbus systems with bus-to-bus technology. Mutually compatible components specially developed for the demands of process technology allow you to speedily plan and commission your fieldbus system and to operate your plant safely and efficiently. FieldConnex™, the fieldbus installation technology from Pepperl+Fuchs – for PROFIBUS and FOUNDATION Fieldbus.



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